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ANALYSIS OF V-G RECORDS FROM

THE SNJ-4 AIRPLANE

By M. Wilkerson and S. A. Bennett

**Langley Memorial Aeronautical Laboratory
Langley Field, Va.**

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NACA LANGLEY MEMORIAL AERONAUTICAL LABORATORY

MEMORANDUM REPORT

for the

Bureau of Aeronautics, Navy Department

RESTRICTED

MR No. L5L06

ANALYSIS OF V-G RECORDS FROM

THE SNJ-4 AIRPLANE.

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SUMMARY

An attempt has been made to adapt a method of analysis of V-G data from transport operation previously reported in NACA ARR No. L5J04 entitled "A Method of Analysis of V-G Records from Transport Operations" by A. M. Peiser and M. Wilkerson to the analysis of maneuver loads obtained with military aircraft. It was found that the previously developed method could be applied, with slight modifications, to data of the maneuver type obtained from the SNJ-4 airplane. The results of the analysis are presented in this report in the form of "flight envelopes" which predict the occurrences of large values of airspeed and acceleration.

INTRODUCTION

A method of predicting the occurrences of large values of airspeed and acceleration from existing V-G records has been developed (reference 1) for application to gust data from commercial transport airplanes. This method involves the construction of "flight envelopes" which predict that, on the average, in a stated number of flight hours, the maximum value of airspeed will be exceeded once, and one positive and one negative acceleration increment will exceed the envelope with equal probability of being experienced at any airspeed.

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The existence of V-G data from military aircraft in which the principal accelerations arise from maneuvers naturally suggests that this method be adapted to the analysis of maneuver data. The lack of symmetry in these data of positive and negative acceleration increments and the frequency of occurrence of maneuvers at high speeds make it apparent that certain modifications are necessary in the application of the method of reference 1 to maneuver data.

Data of the latter type were available in the form of photographic copies of V-G **records**, taken from military aircraft, which were supplied the NACA by the Bureau of Aeronautics, Navy Department, in January 1945. Since more records were received from the SNJ-4 than from any other airplane, the present analysis was confined to the data from that type aircraft. Although data are not available in sufficient quantities at the present time to permit the establishment of definite rules of procedure, the analysis of the records from the SNJ-4 has suggested modifications in the methods of reference 1 which may be expected to apply to aircraft of similar type and mission. The purpose of this report is to present these modifications and indicate, in terms of the data from the SNJ-4 airplane, the nature of **the results that may be expected** from the application of this modified method to V-G data from other military aircraft of similar type and mission.

SCOPE OF DATA

The data which were submitted to the NACA by the Bureau of Aeronautics were enlarged photographs of V-G records with the appropriate calibration superimposed. There were 80 such records from the SNJ-4 airplane taken during typical training maneuvers such as diving, glide bombing, simulated combat, cross-country flights, combat acrobatics, etc. Supplementary data sheets accompanied these photographs which supplied such information as flight hours on each record and type of mission, and which verified the assumption that the large accelerations were largely due to maneuvers rather than turbulence.

Two of the photographs were not readable so that 78 records, representing approximately 275 hours of operation, were available for the current analysis. The

flight time per record varied from 0.8 to 10.9 hours. Since the method of analysis of reference 1 requires that the flight time be held reasonably constant not all the records were used. Over half of the 78 records showed flight times of less than 2 hours, however, so it was decided to limit the analysis to this group. Thus, only 40 records, representing 42 hours of flight, have been used for the analysis herein. The remaining data were utilized to check the final envelopes.

METHODS AND RESULTS

The analysis of the data has roughly followed the methods of reference 1. From each record selected for analysis five values were read: the maximum airspeed V_{max} , the maximum positive and negative acceleration increments Δn_{max} , and the airspeed V_0 at which these accelerations were experienced. The frequency distributions of V_{max} , Δn_{max} , and V_0 obtained from these records are presented in table I.

Briefly, the procedure is to fit each of the frequency distributions with a Pearson Type III probability curve so that estimates may be made of the probabilities, P_V and $P_{\Delta n}$, respectively, that given values of airspeed and acceleration will be exceeded, and the probability P_0 that the maximum acceleration increment on the record will occur in a given speed range. The probability curves for V_{max} , Δn_{max} , and V_0 are presented in figures 1, 2, and 3, respectively. The extrapolations to the V_0 curves are shown by dashed lines in figure 3.

Since the original method was developed for application to gust-load data, certain changes are necessary in the application to maneuver-load data. The following modifications have been made:

- (1) The positive and negative acceleration increments are analyzed separately.
- (2) The straight-line extrapolations (on semi-log paper) to the V_0 probability curve corresponding to positive acceleration increments is made at the maximum

level-flight speed of the airplane (205 mph for the SNJ-4). The extrapolation for the V_0 curve corresponding to negative acceleration increments was made at the normal cruising speed of the airplane (170 mph for the SNJ-4) as in reference 1.

The values of P_v , $P_{\Delta n}$, and P_0 taken from figures 1, 2, and 3 have been combined to obtain flight envelopes which predict that, on the average, in a stated number of flight hours, one airspeed will exceed the envelope and one positive and one negative acceleration increment will exceed the envelope with equal probability of being experienced at any airspeed. The flight envelopes for 250 and 1000 hours of flight with the SNJ-4 airplane are shown in figure 4. The detailed procedures by which these envelopes are constructed are explained fully in reference 1.

DISCUSSION

The flight envelopes obtained in this report predict that, on the average, in a stated number of flight hours, one airspeed, one positive acceleration, and one negative acceleration will exceed the envelope with equal probability of the accelerations being experienced at any airspeed. An opportunity for testing the accuracy of this prediction is afforded by the fact that the envelopes are based on only 42 of the 275 hours of available records. In figure 4 the actual composite of the entire 78 records is compared with the 250-hour flight envelope derived from the 40 selected records. It will be noted that one negative acceleration increment exceeds the envelope. Although this is not in exact agreement with the predicted conditions, the accuracy seems reasonable on the basis of a single analysis since the envelopes constitute a statistical prediction which is based on average conditions and can be verified only upon the examination of a considerable body of data. While the results of the present method seem promising, further verification must, of course, depend on additional analyses from different airplanes operating on various types of missions.

The application of the method of reference 1 for different flight conditions has a certain dependency on a knowledge of the airplane mission and of the aerodynamics involved. It might be pointed out that, whereas

gust data essentially remain uniform regardless of sign, data on maneuver loads will, in general, show higher load factors in the positive direction than in the negative. It is also true that the speed at which the larger accelerations are encountered, which determines the point at which the extrapolation to the V_0 curve is made, is a function of the operating conditions or mission of the airplane and great care is necessary in making such an extrapolation. As a general rule, the point of contact is roughly at the maximum speed at which the largest acceleration on a record is expected to be encountered but the actual fitting of the extrapolation must be done by trial and error and by testing against a composite of the basic material. Thus, for the airplane on which gust loads predominate, it has been found that cruising speed is a reasonable point for the extrapolation since in rough air pilots tend to slow down rather than to speed up. For training flights, say of pursuit pilots, the maximum load factor may be experienced well above the maximum level-flight speed during such missions as ground strafing or dive bombing, while for other types of aircraft or missions the maximum accelerations might seldom occur above maximum speeds in level flight. The data would then require that the extrapolation be started at a different point in each case. These items, mainly the dissymmetry of the V-N diagram and the speeds at which large accelerations are liable to be encountered, require careful consideration and in all cases limit any analyses to the prediction of load experiences under similar conditions. This extrapolation thus emphasizes the fact that in analyzing V-G type records care must be taken in sorting the records by the flight conditions of which the records are considered a sample.

In regard to the application of statistical procedures to flight maneuver data where extreme values of speed and load factors may be experienced it might be noted that when a discontinuity in the airplane characteristics occurs statistical procedures of any type may not be applicable. An example of this might be the attempt to predict the maximum load factor for a high-speed airplane where the basic data are taken at speeds and accelerations below the critical Mach number. Such data will not recognize the limits on load factors or changes in stability caused by exceeding critical Mach number and therefore may yield incorrect results and would be dangerous. A similar problem would be that of predicting the maximum load factor at lower speeds and

attempting to go beyond the stalling conditions for the airplane. In any of these analyses care must be taken to check the results against the physical limits imposed on the airplane by aerodynamic or other factors. This problem arises both in the prediction of the maximum speed to which the airplane will be flown as well as the maximum load factors that will be imposed on the airplane.

As in the case of the data presented in reference 1, the most straight-forward but very laborious process of computing the probability curves for different speed brackets was also done for comparison with the method used herein and indicated that within the limits of accuracy of the data, the two methods yield essentially the same results. While the bracket system lends itself to a more routine type of analysis, the amount of work required and the accuracy of the results do not appear to warrant its use. Although the computer can arrive at the answer by a more routine procedure with the bracket system, it is doubtful that the increased accuracy, if any, would be worth the effort.

In reference 1 it was shown that the record time should be kept essentially constant and for gust data it would appear that a two-to-one variation is not too serious. This criterion was used in the present analysis since there was not sufficient data available to investigate the importance of record time. It appears reasonable, however, in the light of the information in reference 1 to maintain a uniform flight time per record, if possible, if for nothing more than convenience in treating the final data. It also appears desirable, in order to give the analyst a more flexible set of data, to keep the individual record time to a minimum and in this way permit him to sort his records by mission as well as enable him to have as many points as possible available for the determination of his probability curves. It appears on the basis of past experience that to determine probability curves in an adequate manner at least 25 records for each type of mission would be required.

CONCLUDING REMARKS

A method which was developed for the analysis of gust-load data from V-G records has been applied, with slight modification, to the analysis of maneuver-load

data. While the results obtained appear satisfactory on the basis of the limited data available, further verification must await the examination of additional records from similar type aircraft. This modified procedure offers promise for utilizing information from V-G records on problems of predicting flight loads and speeds for airplanes on which loads due to maneuvers predominate.

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REFERENCE

1. Peiser, A. M., and Wilkerson, M.: A Method of Analysis of V-G Records from Transport Operations. NACA APR No. L5J04, 1945.

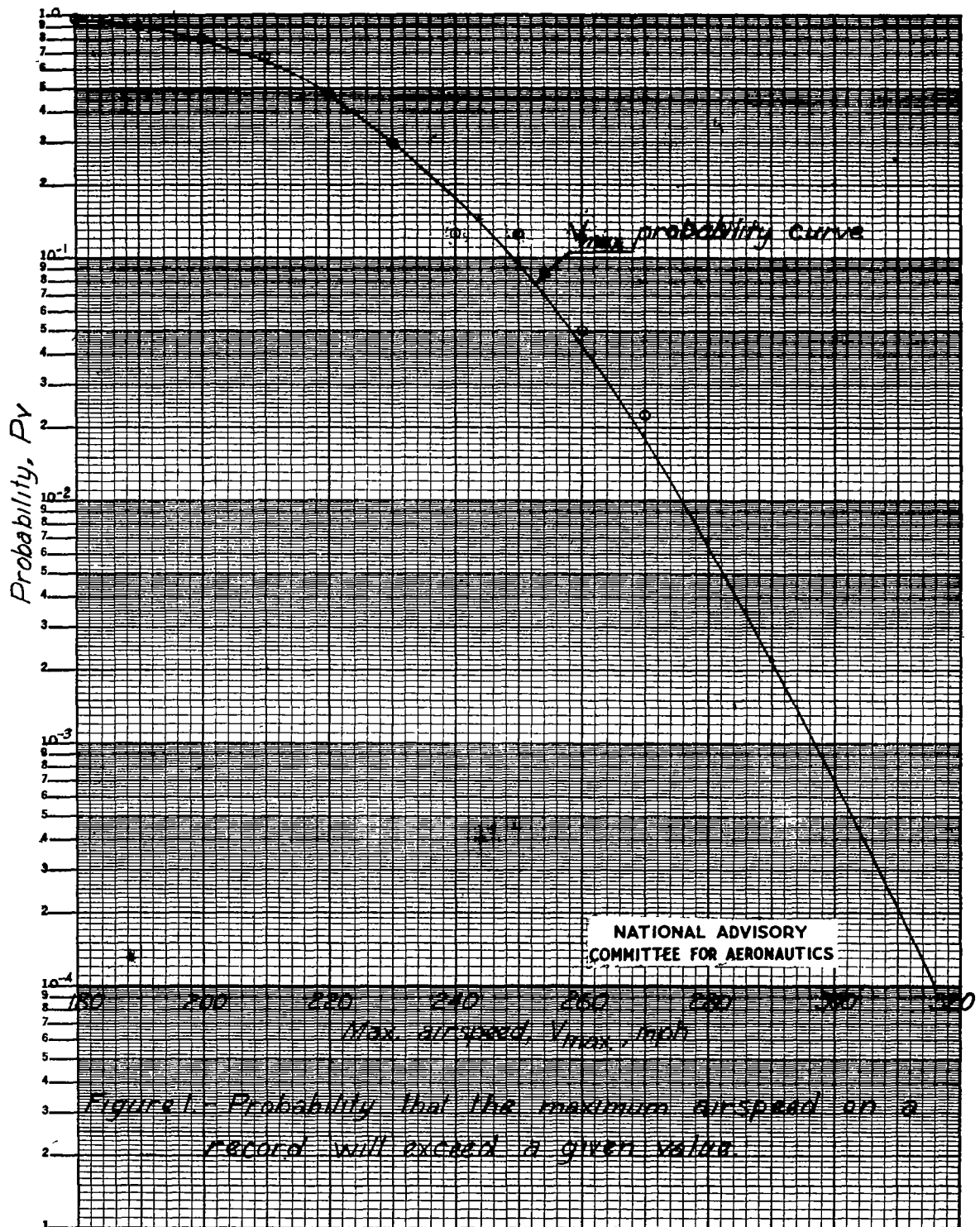
TABLE I

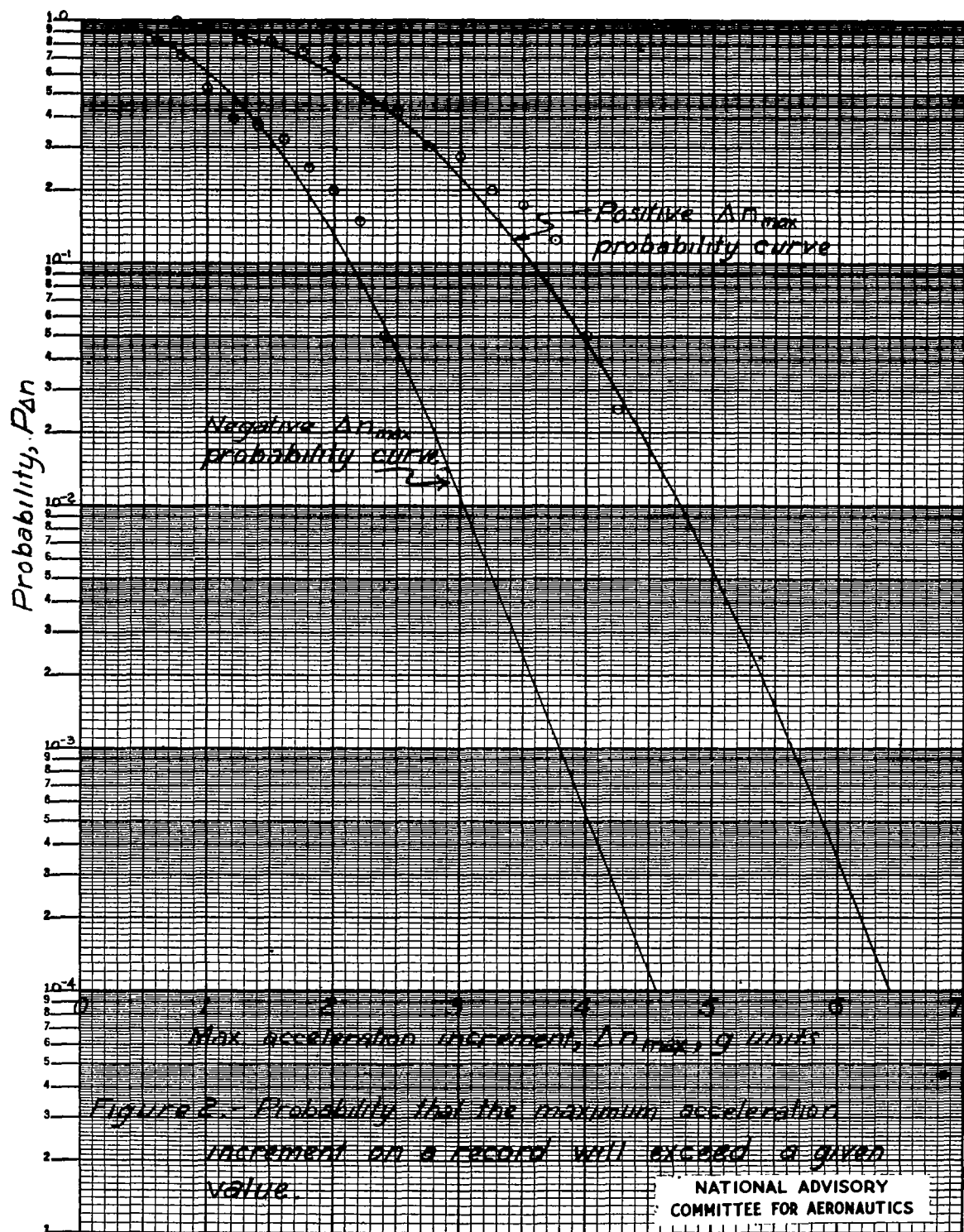
FREQUENCY DISTRIBUTIONS AND PARAMETER VALUES FROM SNJ-4 RECORDS

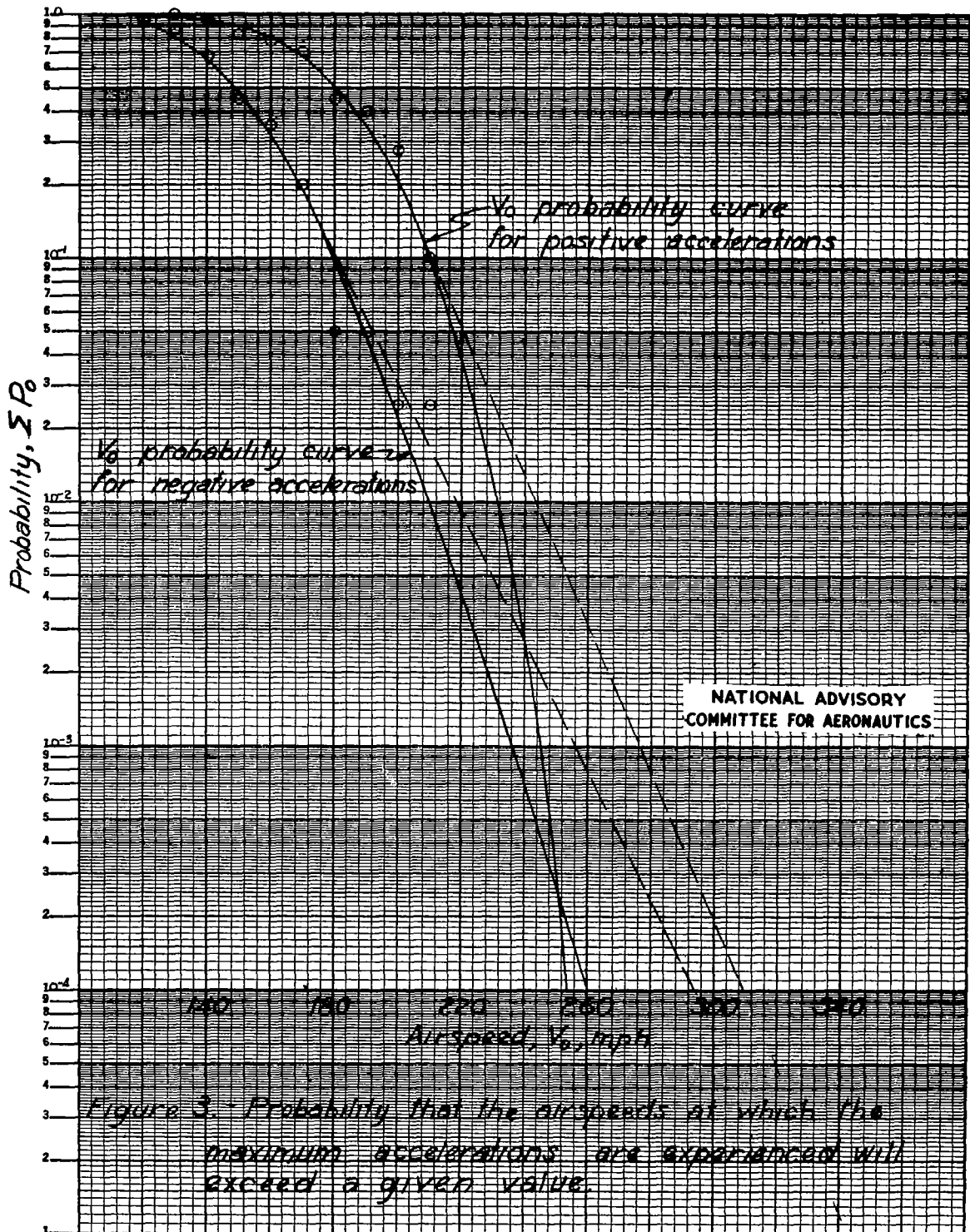
V _{max} distribution		Positive accelerations				Negative accelerations			
V _{max} (mph)	Fre- quency	Δn _{max} (g)	Fre- quency	V _o (mph)	Fre- quency	Δn _{max} (g)	Fre- quency	V _o (mph)	Fre- quency
160 - 169	1	0.75 - 0.99	1	130 - 139	2	0.20 - 0.39	3	100 - 109	1
170 - 179	0	1.00 - 1.24	5	140 - 149	5	.40 - .59	4	110 - 119	1
180 - 189	3	1.25 - 1.49	1	150 - 159	2	.60 - .79	4	120 - 129	3
190 - 199	4	1.50 - 1.74	3	160 - 169	3	.80 - .99	3	130 - 139	10
200 - 209	5	1.75 - 1.99	2	170 - 179	10	1.00 - 1.19	5	140 - 149	7
210 - 219	8	2.00 - 2.24	9	180 - 189	2	1.20 - 1.39	1	150 - 159	4
220 - 229	7	2.25 - 2.49	2	190 - 199	5	1.40 - 1.59	2	160 - 169	6
230 - 239	7	2.50 - 2.74	5	200 - 209	7	1.60 - 1.79	3	170 - 179	6
240 - 249	0	2.75 - 2.99	1	210 - 219	4	1.80 - 1.99	2	180 - 189	0
250 - 259	3	3.00 - 3.24	3			2.00 - 2.19	2	190 - 199	1
260 - 269	1	3.25 - 3.49	1			2.20 - 2.39	4	200 - 209	0
270 - 279	1	3.50 - 3.74	2			2.40 - 2.59	2	210 - 219	1
		3.75 - 3.99	3						
		4.00 - 4.24	1						
		4.25 - 4.49	1						
$\overline{V_{max}} = 210.75$ $\sigma = 22.90$ $\alpha = 0.172$		$\overline{\Delta n_{max}} = 2.41$ $\sigma = 0.921$ $\alpha = 0.328$		$\overline{V_o} = 179.75$ $\sigma = 23.87$ $\alpha = -0.228$		$\overline{\Delta n_{max}} = 1.25$ $\sigma = 0.667$ $\alpha = 0.448$		$\overline{V_o} = 150.75$ $\sigma = 21.78$ $\alpha = 0.537$	

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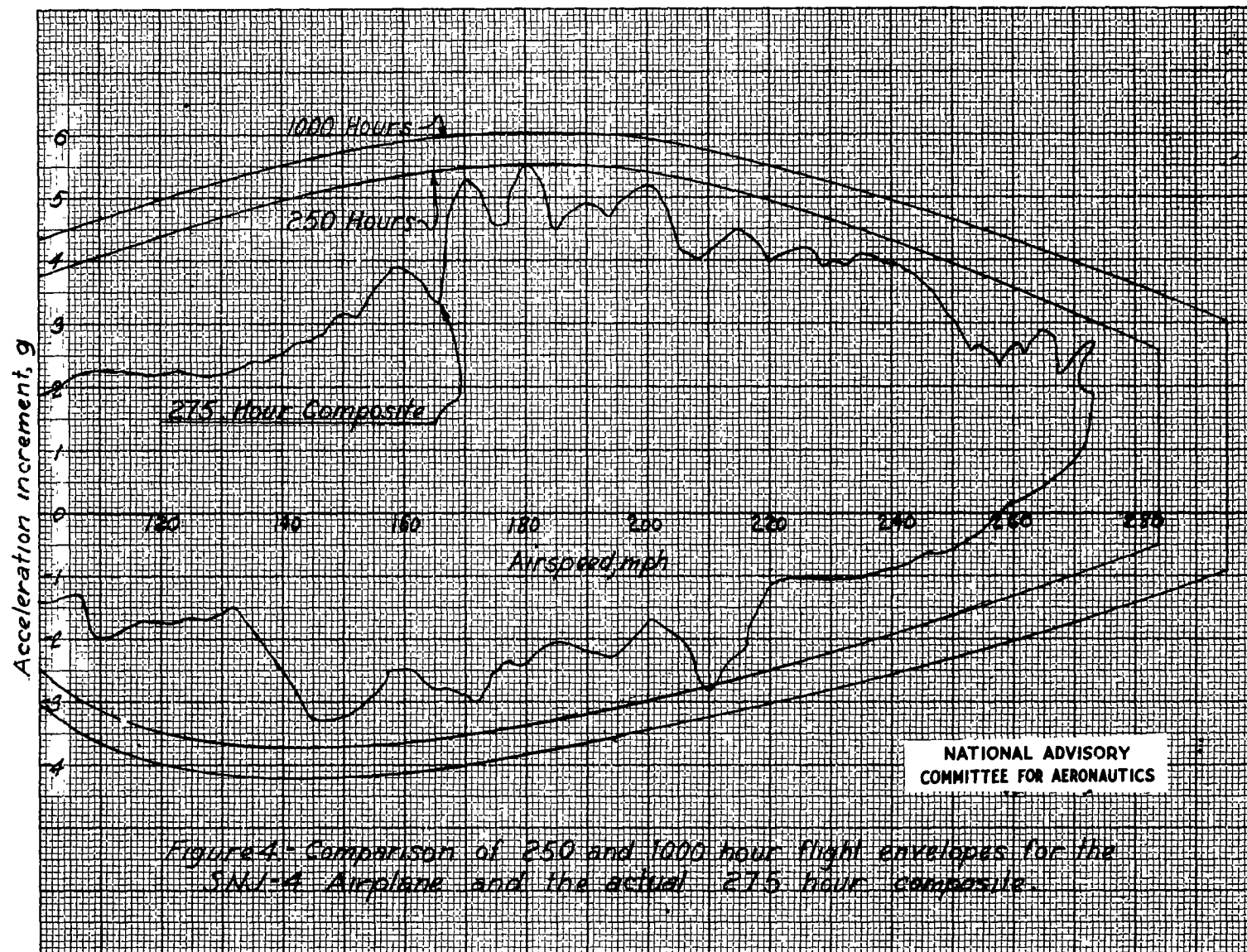


Figure 4.- Comparison of 250 and 1000 hour flight envelopes for the SNJ-4 Airplane and the actual 275 hour composite.



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